Antenna Pattern Measurement System

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What is an Antenna Pattern Measurement System?

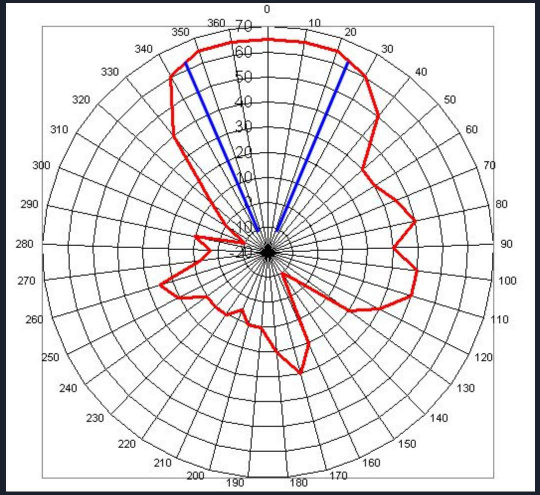
Antenna pattern measurements are used to determine how the magnitude and phase of signals transmitted by a specific antenna and waveguide change with angle relative to the receiver.

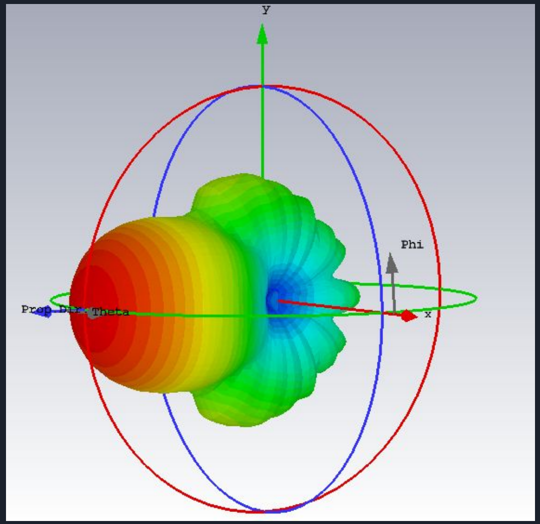
The main focus of an Antenna Pattern Measurement system is to be able to determine an antennas gain and directivity properties.

Directivity - the ratio of electromagnetic radiation of a real antenna at an azimuth or elevation angle to its radiation in all directions averaged over a sphere, if measured in the far field.

Gain - the maximum signal intensity of an antenna at a specific vertical or horizontal angle

By taking measurements at enough points surrounding the antenna, we can construct a (2D or 3D) map that makes the properties of each antenna easier to understand and visualize.





Project Vision

The goal of this project is to create an <u>affordable</u> way to quantify and visualize different types of antennas without sacrificing too much time or accuracy.

- Example : Milibox 4ft Compact mmWave anechoic chamber
  - Cost > $18,000 !

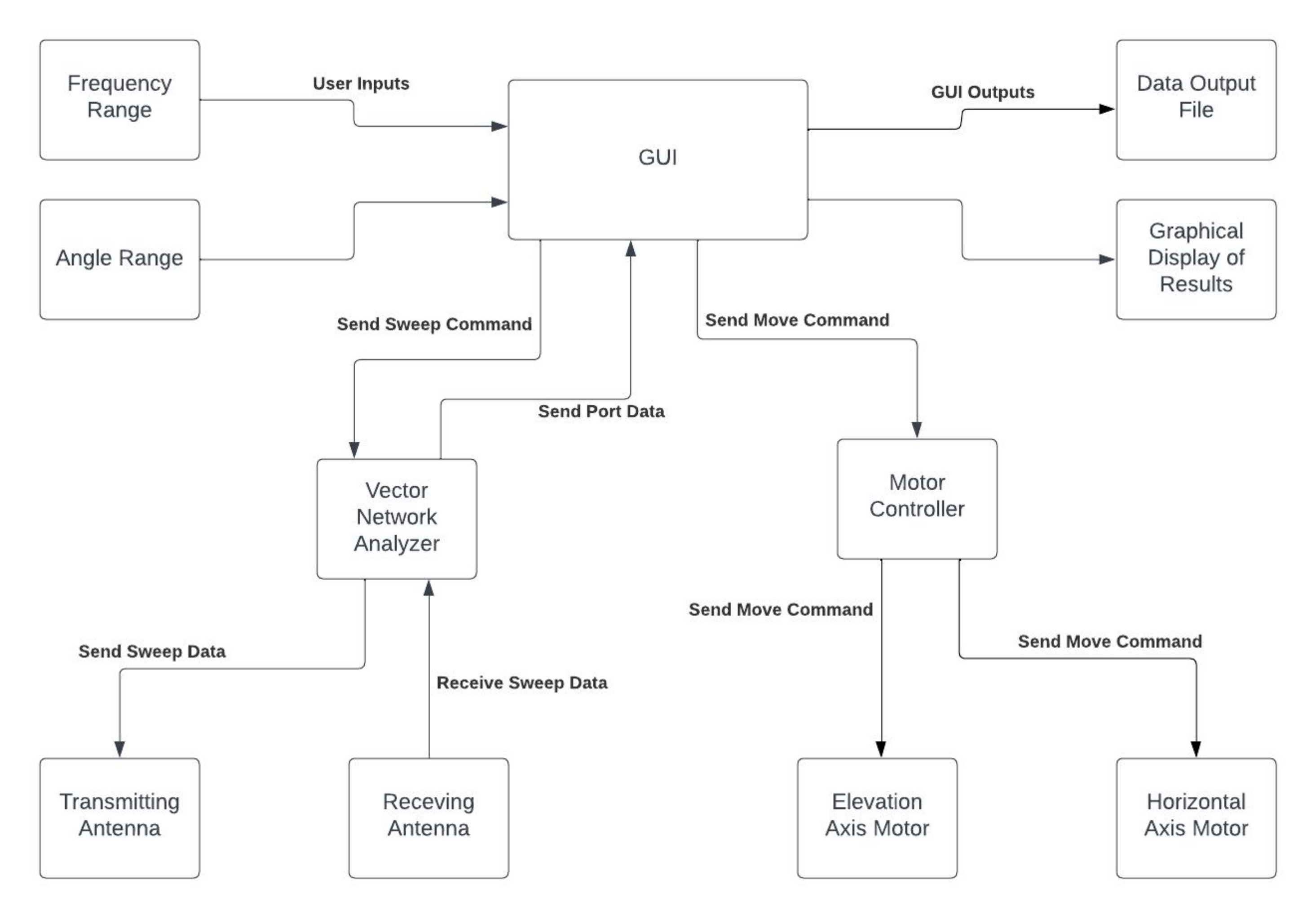
Who cares?

- Professors teaching E&M (EE311), Antenna Design (EE417/EE517), and related subjects (lower cost makes it applicable to them)
- Researchers verifying antenna designs/characteristics

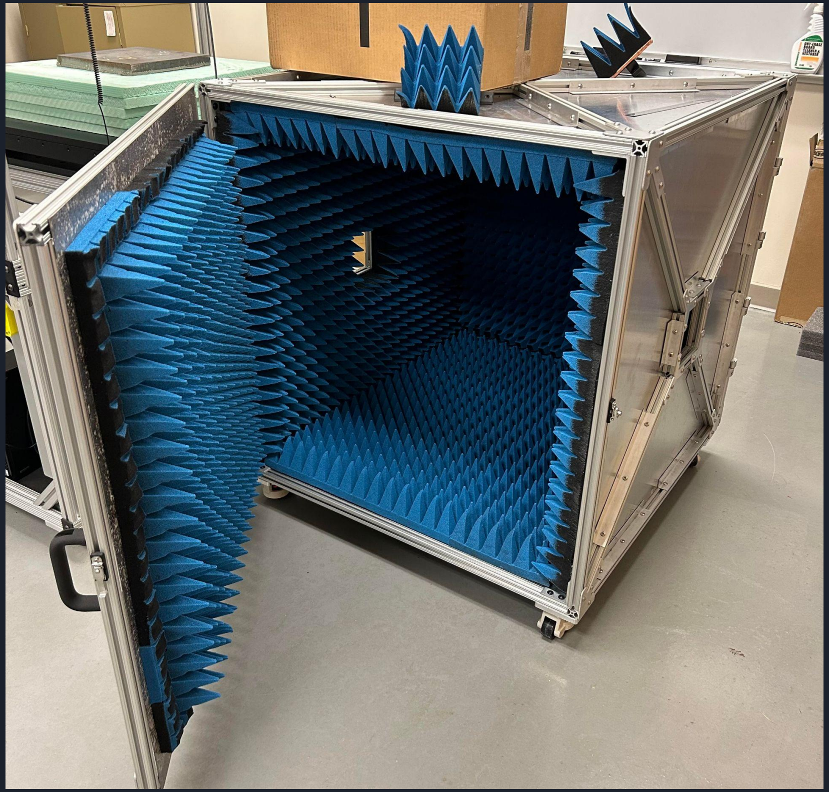
General Approach

Accomplished by using two stepper motors to rotate a transmitting antenna (up/down, left/right) while sending a signal to the receiving antenna. Our software will use the data to create a map of signal strength at different angles.

Conceptual Design Overview

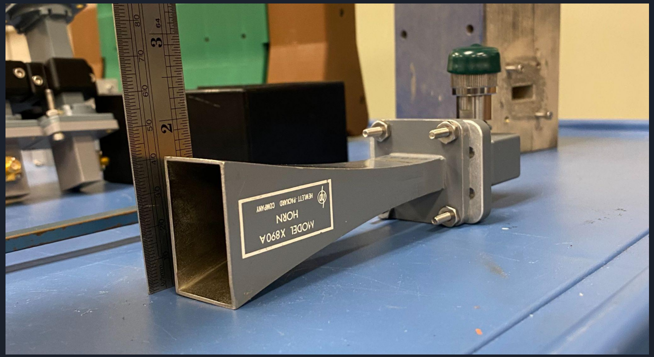


Equipment Overview



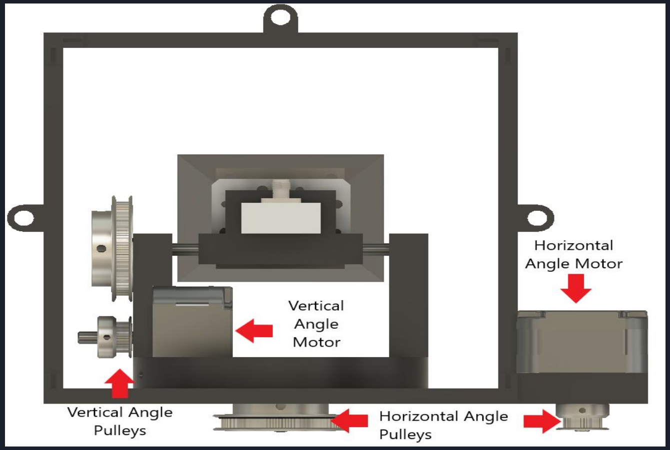
3’x3’x3’ Anechoic Chamber

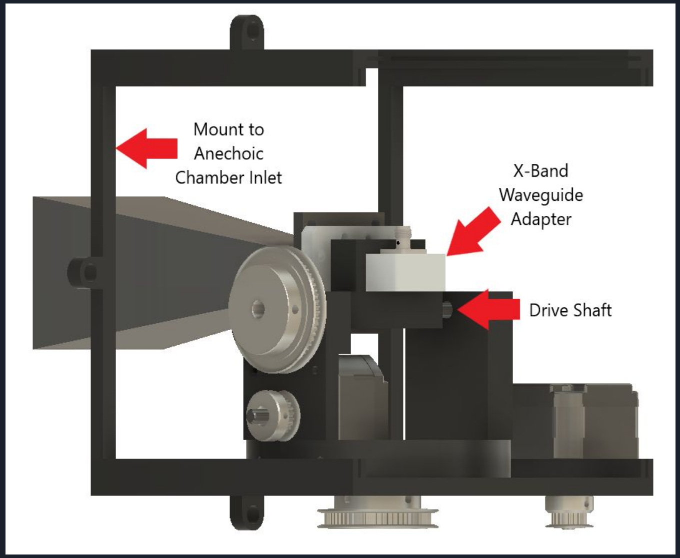
Fieldfox 2–Port VNA

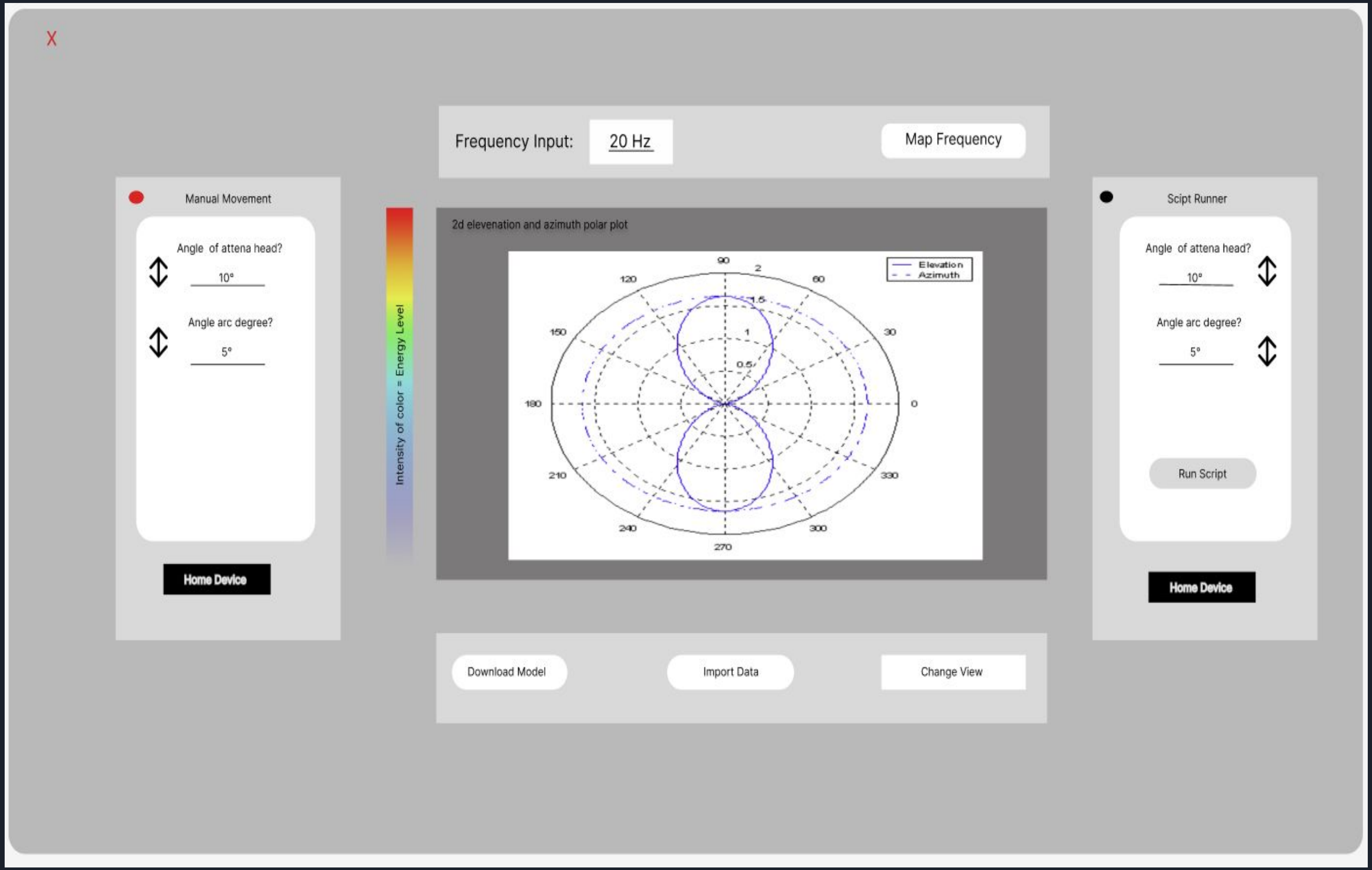


X-Band Horn Antenna

Designs and Visuals of Project







Software Requirements

<u>**Functional:**</u>

Event-Driven:

- When a manual script is run the software shall not allow automated script cannot be used. Vice versa
- When map frequency is clicked the software shall compute the associated 2D polar graph with it.
- When home device button is clicked the software shall automatically bring the antenna back to natural state.

State-Driven:

- While in manual script mode the software shall not allow automated script mode to be used. Vice versa
- While data is being collected the software shall not allow other functionalities to be used.

Unwanted Behavior :

- If VNA or hardware stops collected data in the middle of a run the software shall alert the user and terminate process.

Software Requirements

Non-functional:

Security:

- Integrity: The data coming in from the VNA shall be the same as the data being presented on the downloadable excel sheet

Maintainability:

- The software shall support easy addition of new sized antennas.

Usability:

- The software shall produce a 2D polar plotted graph of each frequency and angle input that is easy to view.
- The software shall have all functionality on one page.

Performance:

- The software shall be able to produce a graph with a frequency and angle within 1 minute of user input.
- The software shall download data to host computer within 2 minutes.

Hardware Requirements and Constraints

- Transmitting antenna must be able to rotate at least 60° about two axes, vertical and horizontal
- Stepper motor target step size of 0.6° (achieved through 3:1 pulley system)
- Stepper motor minimum holding torque of 12 N*cm (does not include inefficiencies)
- Transmitting and receiving devices must be housed completely inside anechoic chamber
- Both anechoic chamber openings are 5.5” x 5.5”
- Device should support anechoic cones to reduce reflections
- Should be easy to swap waveguides

Design of Mechanical System

<u>Two axis, pulley design:</u>

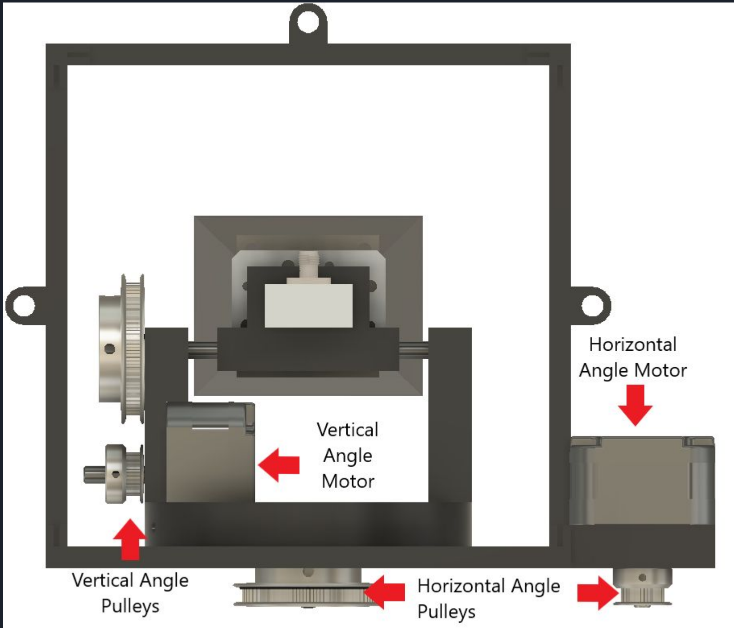
- Provides vertical and horizontal angles of rotation

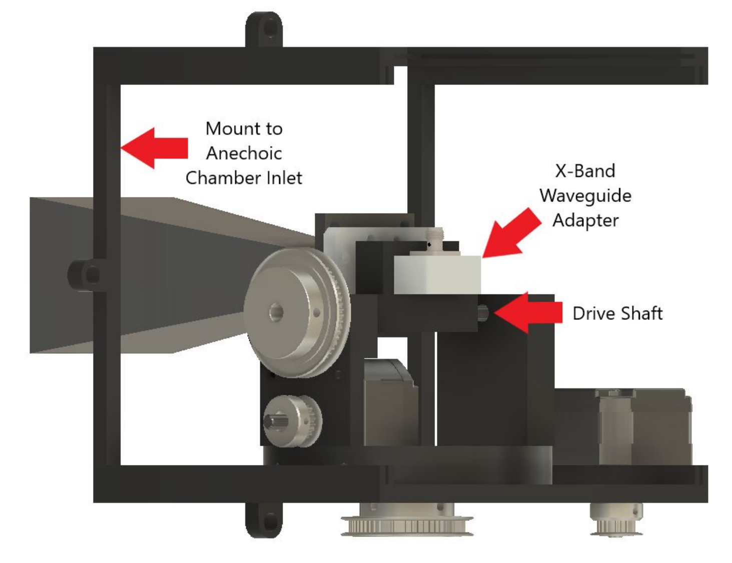
<u>Uses 2x NEMA - 17 stepper motors:</u>

- NEMA-17 motors have rotational resolution of 1.8°
    - Designed pulley system to have a 3:1 Ratio
    - Allows angular resolution of 0.6°
- All components designed around keeping antenna centered

<u>3D Printed Parts include:</u>

- Vertical stage
- Mount to chamber
- Antenna holder
- Designed around X-Band waveguide adapter
- Easy transition between waveguides

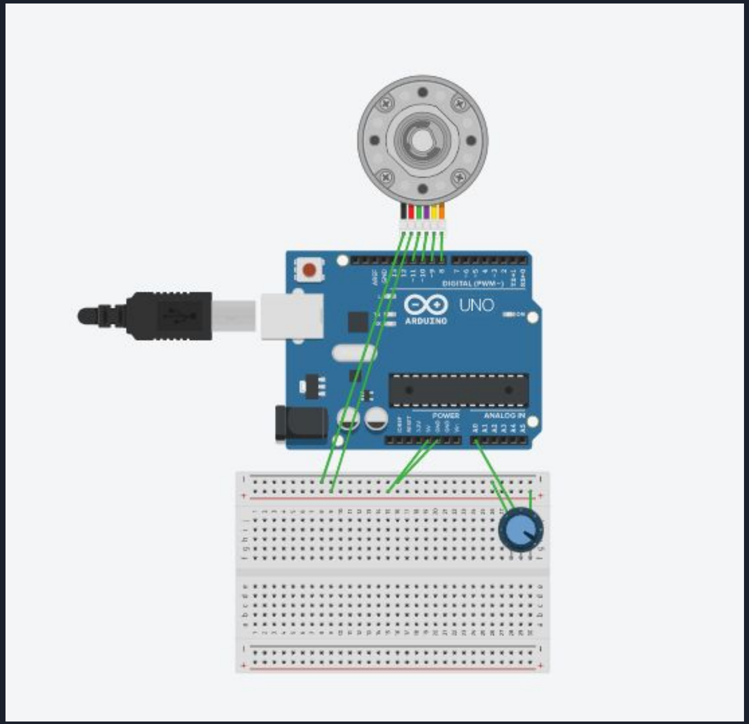




Prototyping Firmware

Script Runner:

- Inputs on the specified horizontal and elevation axis (Limitations may vary on both axis due to wiring constraint).
- Resolution and position tracker to reposition back to home before running an new test.
- Supply sufficient power on both the controller and the 2 NEMA-17 motors.
- Degree measurements to verify that the motors are producing 3:1 ratio at 0.6 degrees per step.

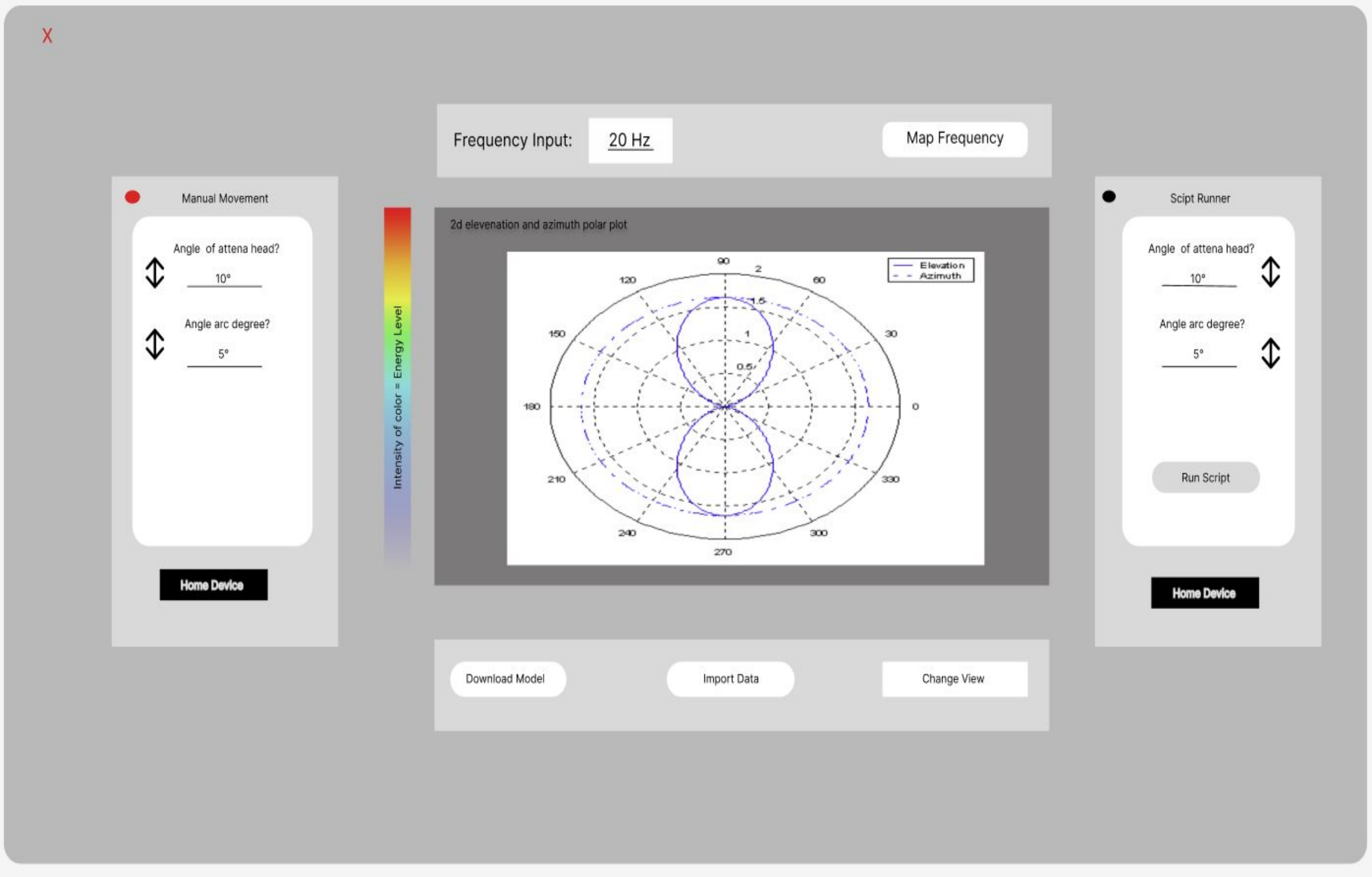



```
#include <Stepper.h>

const int stepsPerRevolution = 200;  // change this to fit the number of steps per revolution
// for your motor

// initialize the stepper library on pins 8 through 11:
Stepper myStepper(stepsPerRevolution, 8, 9, 10, 11);

int stepCount = 0;  // number of steps the motor has taken

void setup() {
  // nothing to do inside the setup
}

void loop() {
  // read the sensor value:
  int sensorReading = analogRead(A0);
  // map it to a range from 0 to 100:
  int motorSpeed = map(sensorReading, 0, 1023, 0, 100);
  // set the motor speed:
  if (motorSpeed > 0) {
    myStepper.setSpeed(motorSpeed);
    // step 1/100 of a revolution:
    myStepper.step(stepsPerRevolution / 100);
  }
```

Software Design

<u>Software Stack/Framework:</u>

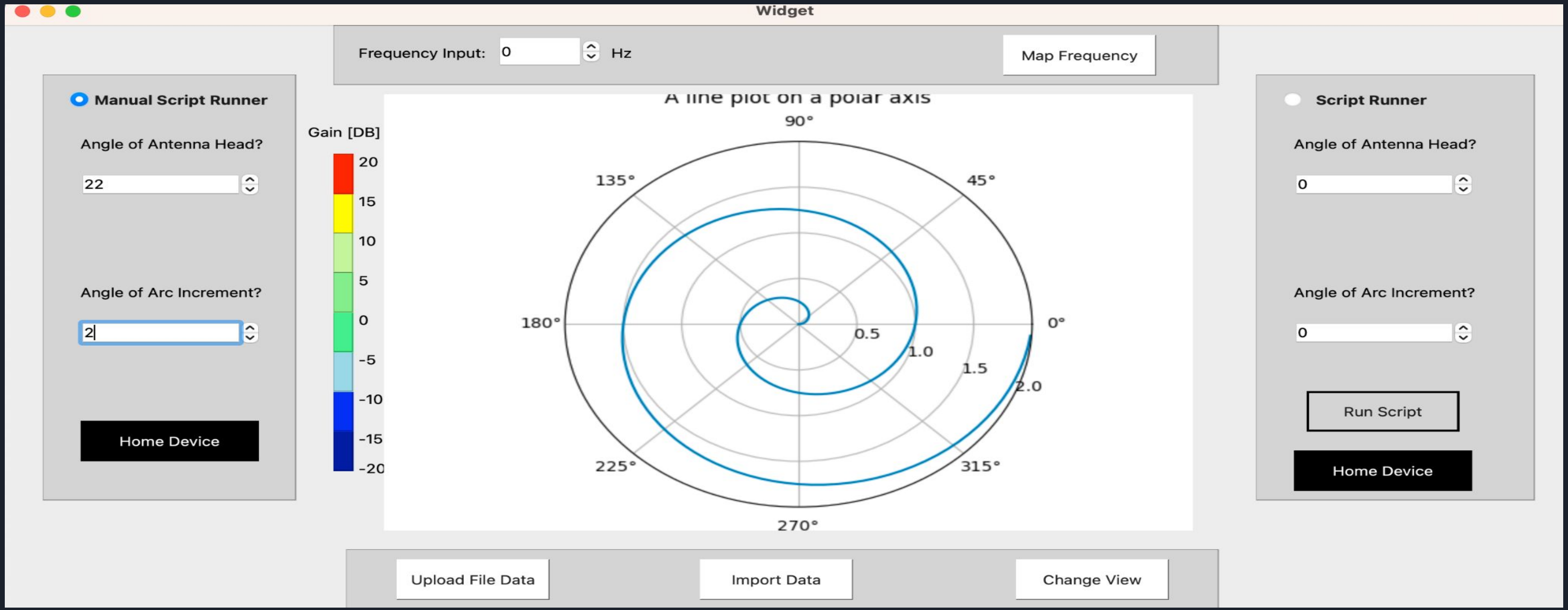
- Data Representation/Logic: Python matplotlib library for 2d plot of radiation antenna data. Python code for logic handling of user input.
- Framework: PyQt6 for desktop application widget and data flow creation.
- Version Control: Github hosts our code base and Github Desktop for branching, pulls, pushes and repository information.



Prototype Implementations

Software:

- UI is created and allows for user input.
- “Map frequency” maps a dummy data plot and displays on UI
- User input is shown on backend and will be used to run scripts for antenna movement.
- Upload file data allows for file upload and will be used to create data plot.




```
  plt.draw()
/var/folders/h6/hmltb5nj6lg59kt7l7qhlg400000gn/T/tmpbazj5rgvwas deleted.
manual runner mode initiated
spinbox1: 2
spinbox1: 22
spinbox2: 2
2022-12-05 18:21:41.391 Python[1351:25576] +[CATransaction synchronize] called within transaction
2022-12-05 18:21:41.508 Python[1351:25576] +[CATransaction synchronize] called within transaction
('/Users/hamzashahid/SE491/softwareDesktopGUI/AntennaAnalyzer/test.png', 'Image Files (*.png)')
uploaded success

Process finished with exit code 0
```

Challenges of the Design

Hardware/Firmware:

- The system requires precise resolution to accurately distinguish the antenna’s position.
- The microcontroller that controls the NEMA-17 motors will be need to communicate with the UI Desktop Application.
- Reducing the effective step angle of the stepper motors takes up valuable space with gear/pulley reduction systems.
- Constrained area to implement design.

Software:

- Antenna movement and timing that the software will take measurements will need to be thoroughly investigated.
    - With the large amount of data being collected make sure that it is read and exported correctly.

Project Plan (Tasks)

Hardware/Firmware:

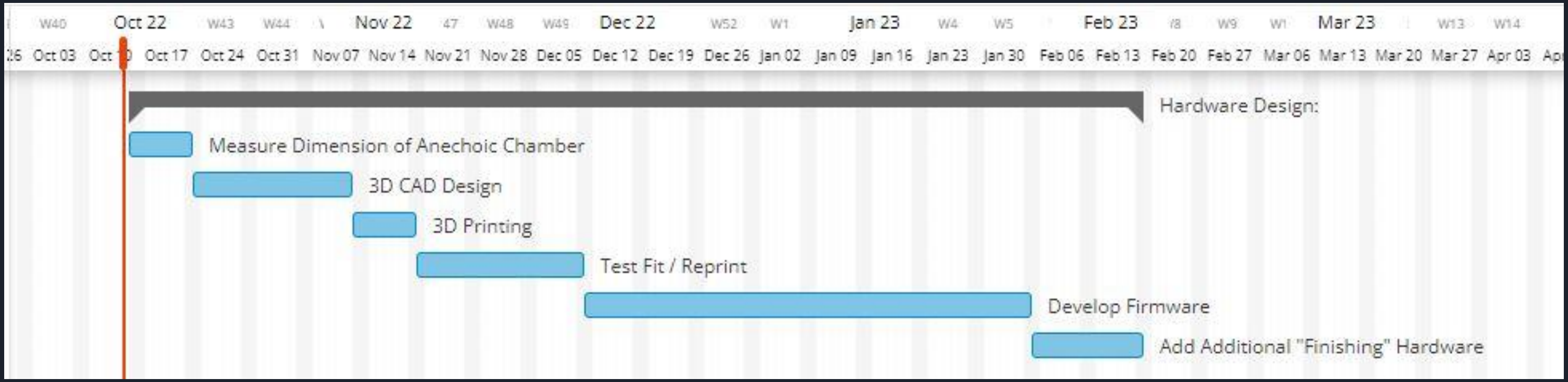
- First needed to find physical constraints of the system.
- Next we need to implement design into CAD software.
- Once designed, obtain stepper motors and motor controllers to begin testing and tuning of the angular resolution.
- Use Fusion 360 to 3D print the anechoic chamber opening mounts.
- Mount and wire 2 stepper motors to control antenna angles of measurement (target angle size 0.6°).

Software:

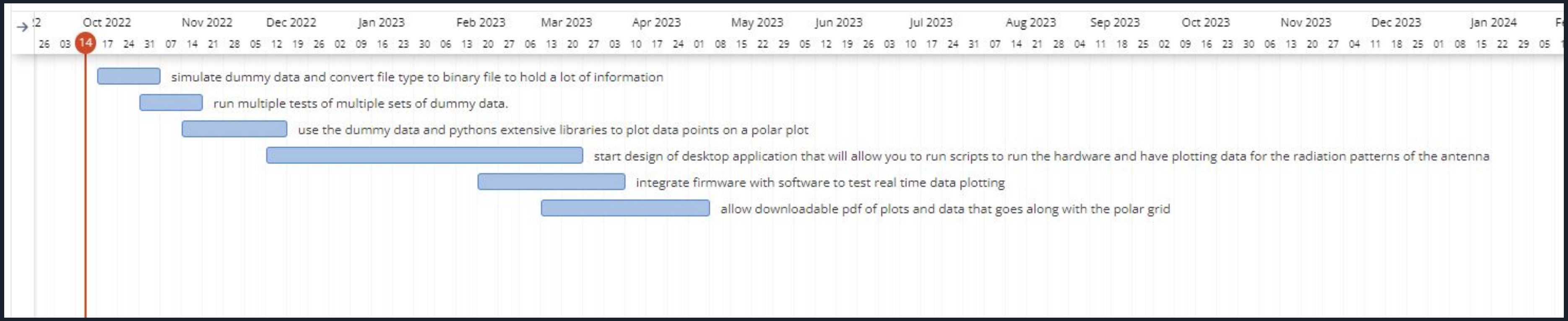
- Simulate dummy data to convert file to binary and back to viable readings to plot our 2D polar graph.
- Development of a desktop application to have accessibility to run scripts, hardware and plotting data.

Project Plan (Schedule and Milestones)

Hardware



Software



Project Plan (Software)

- Integrating the software and firmware will take time.
  - Motors and VNA / Antenna communicate directly with software.
  - Make sure antenna is scanning right frequencies at given angle.
  - Antenna and motors are in sync even though they aren’t communicating with each other.
- Export and import functionality
  - Make sure that the graphs for data that in imported looks correct.
  - Data is imported correctly (right frequency and angle).
  - Data is correctly exported to excel file and matches the data that was collected.
- Extra functionality (if time allows)
  - A 3D graph would better allow users to visualize data.
  - Needs more advanced GUI to view graph from different angles.

Project Plan (Hardware)

- Anechoic Chamber Measurements
  - For design constraints
- Identify specific antennas
  - Also needed for design constraints
- Initial design Sketch
  - Rough draft for 3D modeling
- CAD Implementation
  - Parameterized all entries in design, allowing the design to be easily changed
    - Changes may be needed for different size and shapes of antennas
    - Identified Key errors in design
- Plan to work through these errors throughout the future of the design process

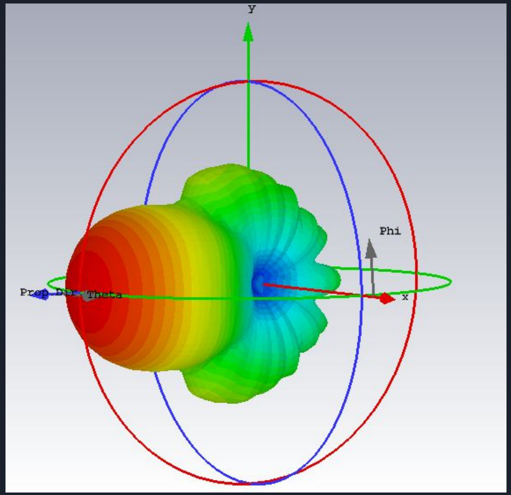
Testing Plan (Interface/Integration Testing)

- Interface Testing includes the software interface between the UI and the motor controller and UI and the Vector Network Analyzer
- Interface between UI and the motor controller
  - Input commands and monitor motor controller that the correct movement command are being output to the motor controller
- Interface between UI and the Vector Network Analyzer
  - Input commands to the Vector Network Analyzer to confirm that desired frequency and points are being used, this can be verified visually on Vector Network Analyzer UI
- Interface between motor controller and pulleys
  - Check expected angle of rotation
  - Calculate error
  - G-Code commands for the motor controller code
- Control Board + Stepper Motors + 3:1 Pulley System + Weighted Load
  - Verify that the pulley reduction is as expected
  - Test with mechanical stress

Testing Plan (System/Acceptance Testing)

System Testing:

- Perform a complete system test, using GUI, Vector Network Analyzer, Motor Controller, and Hardware to ensure functionality
  - Create documentation
  - Identify objectives for operation check
    - Provide warnings if user input could potentially damage system
      - Example : Using to large of an antenna causing to much mechanical stress on 3D printed parts



Acceptance Testing:

- Compare results of system test to CST test results
- If time allows, provide some software that can do this automatically

Testing Plan (Software Unit Testing)

- Radiation Model Display
  - 2D plot of vertical and horizontal planes
  - Testing specific and known radiation patterns
- Script Runner/Manual Runner
  - Homing device has to be clicked before running scripts
  - When a script is ran testing the route of the antenna to make sure it is correct
  - Input should be within a certain range
- Import/Export Data
  - All models from display should be able to be downloaded to host computer
  - Data plotting should be downloaded and have correct values
  - Multiple old files should be able to be uploaded and plotted together

Conclusions

Where are we in our schedule?

- Hardware is currently in the 3D modeling phase due to some setbacks (behind schedule)
- Firmware is currently developing methods to supply power and create trial scripts to send signal to communicate with the controller and the motor (on schedule)
- Software has started building the application (on schedule)

Next semester's plans

- Hardware plans to have an approved design by January 17th in order to begin 3D printing by January 20th
- Firmware plans to develop physical design and measure angles per resolution
- Software plans to finish building the front-end and start building the connections with the motors and VNA

Team member contributions:

Jonathan Insyxiengmay - Leader / Firmware Engineer 1

Aaron Barvincak - Hardware Engineer 1

Alec Gilroy - Hardware Engineer 2

Aryan Prajapati - Software Engineer 1

Hamza Shahid - Software Engineer 2

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